

Flooding and Tropical Wave – August 21-24, 2014

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a. Synoptic History

As August moved into its third week a tropical wave moved across the Atlantic Ocean. It eventually became Hurricane Cristobal after passing the Greater Antilles, however it did not carry high potential for developing a significant tropical cyclone with high winds sooner than that. While approaching the Lesser Antilles the low level atmospheric flow caused it to remain well connected in the intertropical convergence zone (ITCZ). At 800 pm AST on Tuesday, August 19, 2014 it was very uncertain where a strengthening low pressure center might develop, if at all. Figure 1 shows the surface analysis completed by the Ocean Prediction Center at that time, showing an elongated low center or trough, still embedded in the ITCZ, east of Trinidad and north of French Guiana. Some computer models had indicated that the system would continue moving westward into the southern part of the Caribbean Sea though forecasters were not convinced of that scenario. Since the system was still in the ITCZ it had access to a tremendous amount of moisture.

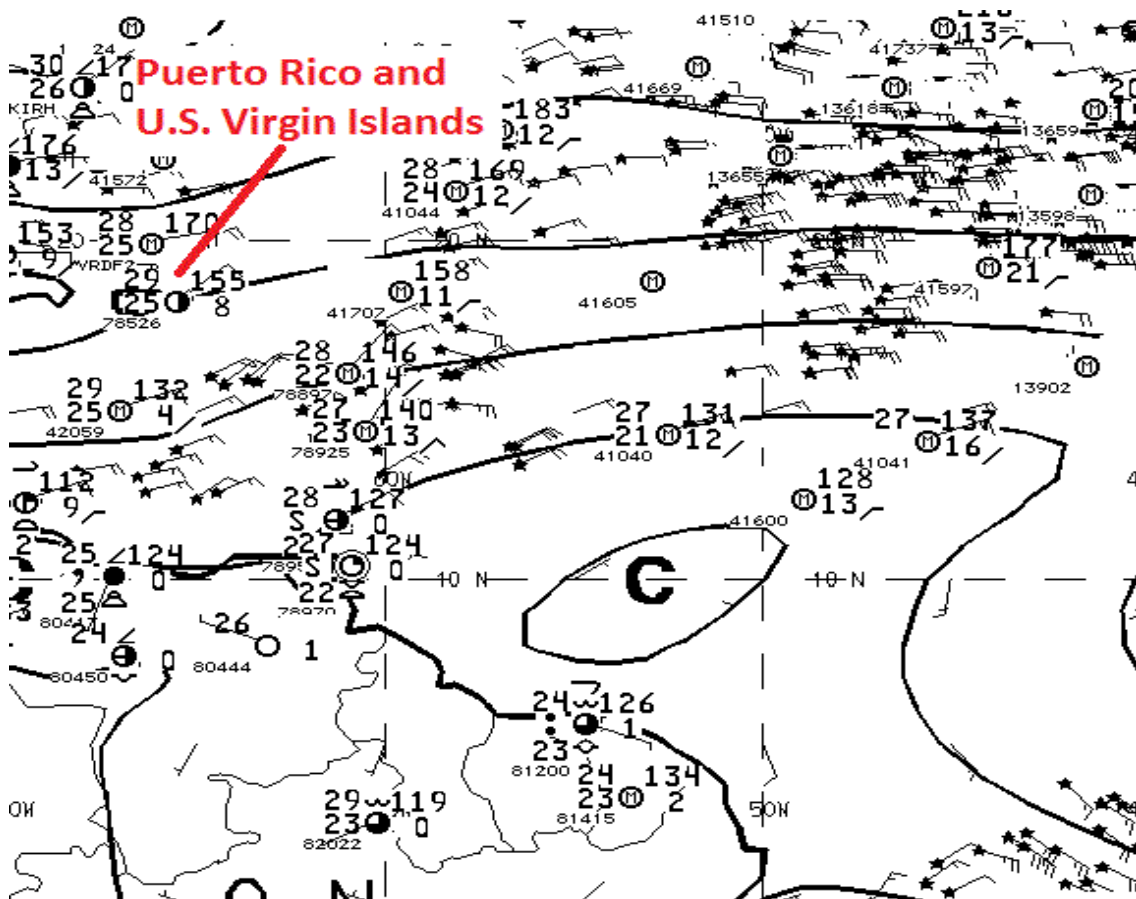


Figure 1. Tropical analysis chart for 0000 UTC on August 20 (800 pm AST on August 19, done by the Ocean Prediction Center.

The Advanced Scatterometer (ASCAT) from satellite (Fig. 2) early on August 20 (Wed.) indicated that it may have been an open wave, between 9°N and 12°N, though the instrument did not cover the western portion of the trough on this pass. Some winds exceeding 30 knots on the east side suggested that further development was possible.

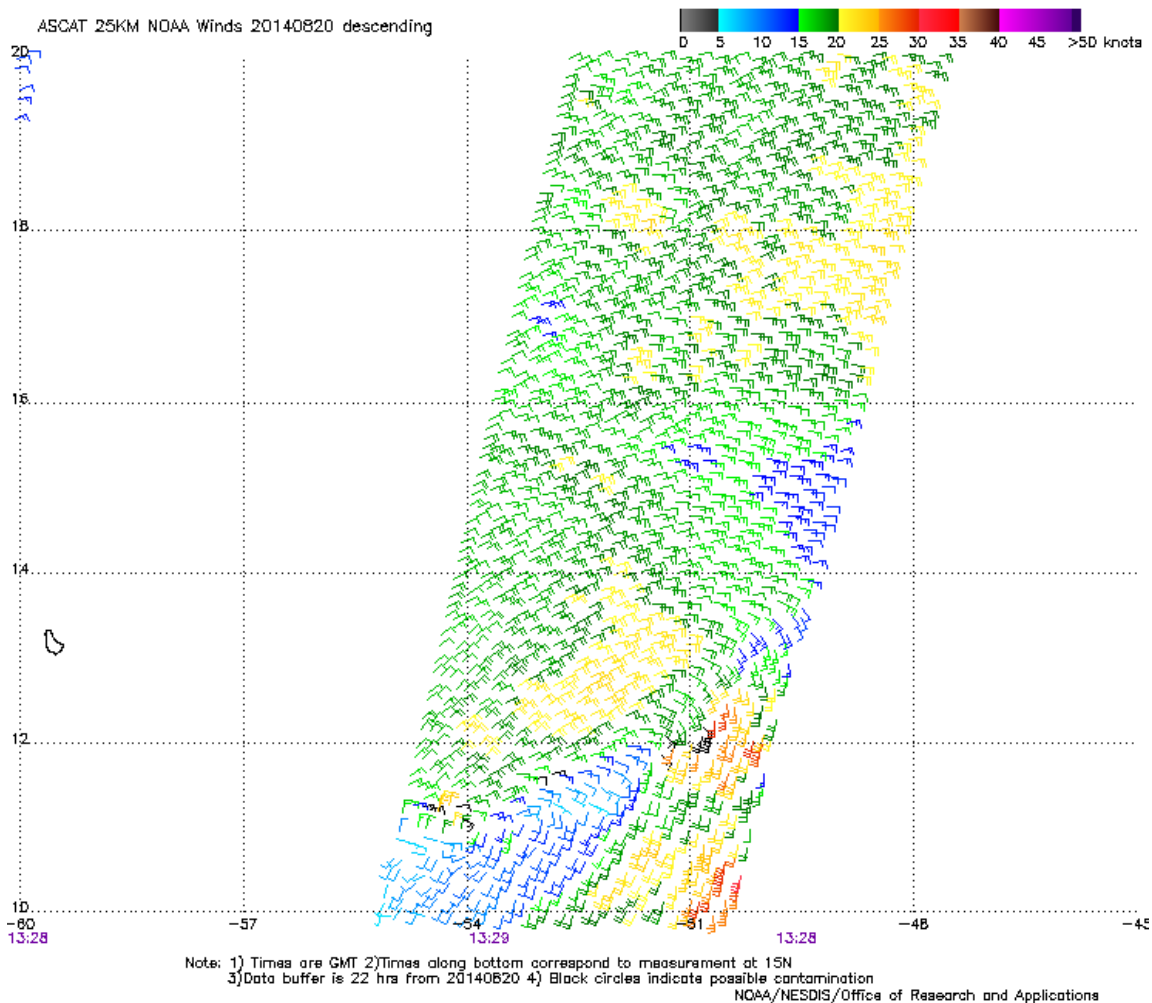


Figure 2. Advanced scatterometer (ASCAT) image on August 20, 2014, east of the Windward Islands, with red indicating the location of 25 to 35 knot winds.

As the trough entered the eastern Caribbean Sea and over the Lesser Antilles late on Thursday and early Friday it was embedded in a very large area of high moisture. Figure 3 shows the horizontal extent of total precipitable water in the wave 0000 UTC (800 pm AST) on August 21. At the same time the upper air soundings at San Juan (TJSJ), Saint Martin (TNCM) and Guadeloupe (TBPB) all measured more than 62 mm (2.45 in.) of precipitable water. Figure 4 shows San Juan recording almost 66 mm (2.58 in.) on their sounding the following morning.

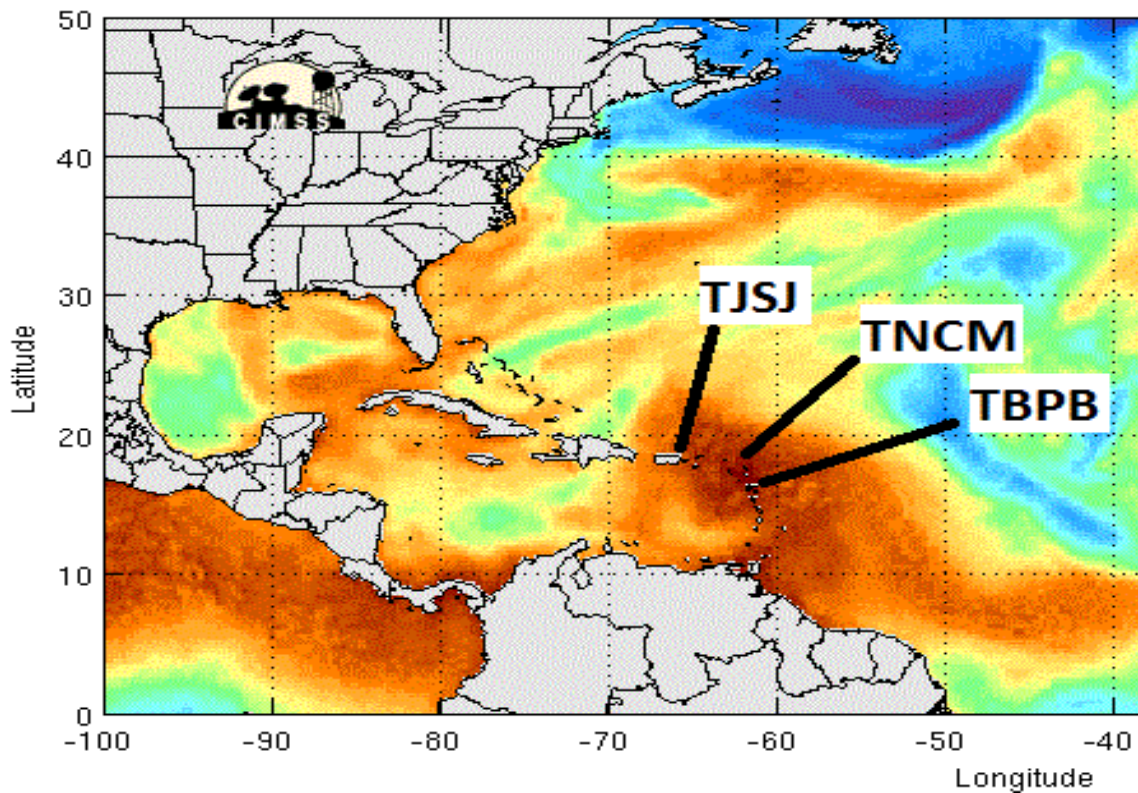


Figure 3. Morphed Integrated Microwave Image at CIMMS – Total Precipitable Water (MIMIC-TPW) early on August 22 showing a large area of total precipitable water in excess of 60 mm (2.36 in.) moving towards local islands.

78526 TJSJ San Juan

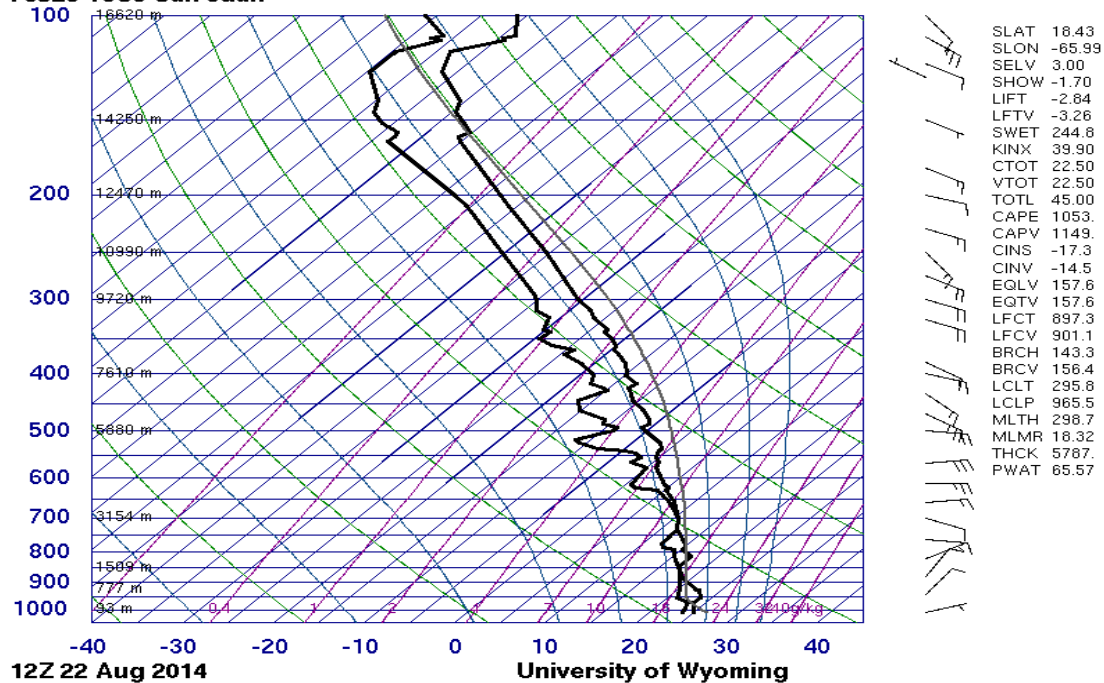


Figure 4. Upper air sounding at San Juan (TJSJ) on the morning of August 22, 2014 with 65.57 mm (2.58 in.) of precipitable water.

This system had copious amounts of moisture yet the associated trough remained a broad circulation for several days. The strongest winds while passing were well north of the local islands (Fig. 5). At nearly the same time as Figure 5, Buoy 41043 at 0950 UTC (450 am on August 22) which is slightly north of this image at 21°N, briefly recorded sustained winds at 30 mph with a gust to 49 mph and then around noon that day it reported waves reaching 11.5 feet. Closer to home, several high wind gusts occurred on the following day (23rd) in convective rain bands. The highest was a 45 mph gust at 148 pm in southeast Puerto Rico, at a buoy (YABP4) located in Yabucoa harbor.

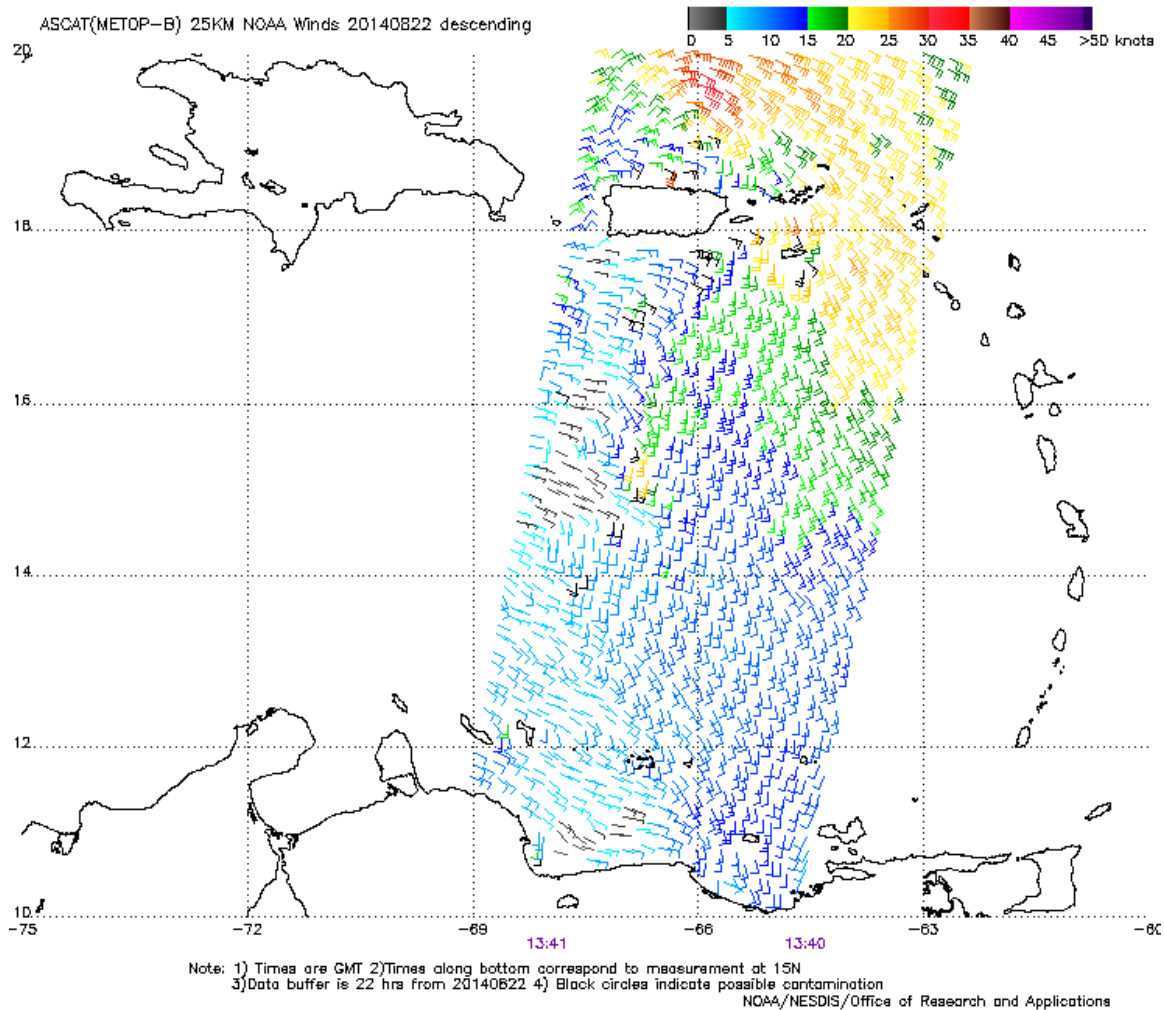


Figure 5. Scatterometer (ASCAT) image early on August 22 showing winds within the trough and strongest winds north of Puerto Rico and Saint Thomas.

b. Meteorological Impacts on Puerto Rico and the U. S. Virgin Islands

The main impact of this system came from very high levels of moisture and resultant rain, and such a long time that it stayed over the islands. The soils were still rather dry after a summer of below normal precipitation but extended periods of heavy showers were more than enough to cause flooding rains. The U.S. Virgin Islands escaped much of the heaviest rainfall though the airport at Charlotte Amalie in Saint Thomas

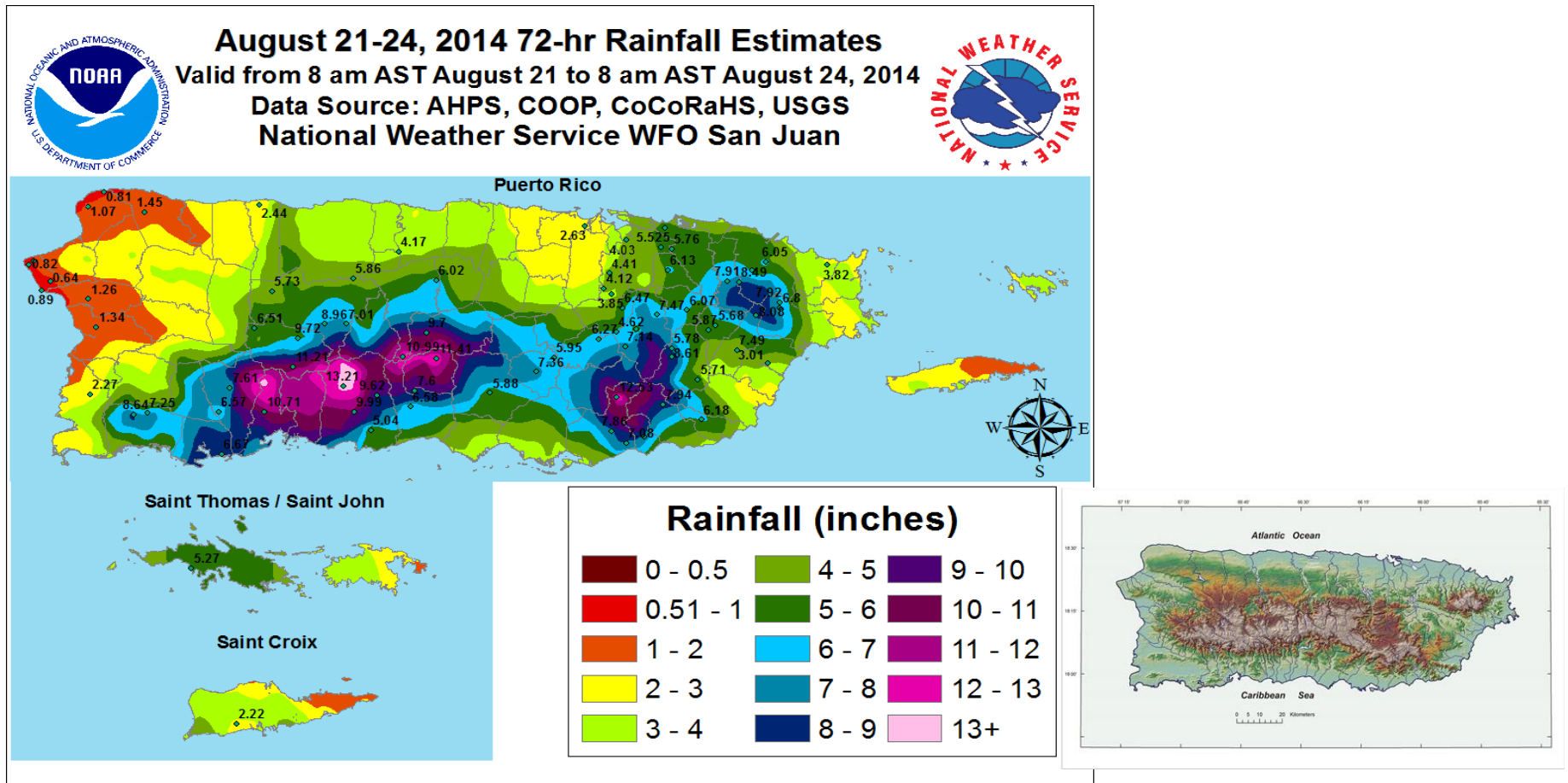


Figure 6. Observed and analyzed precipitation totals for the 72 hours ending on August 24 at 1200 UTC (800 am AST). Values on the map refer to the 72 hour rainfall total for stations in Table 1. A topographic map of Puerto Rico is shown at the right. (Image by Jose Alamo)

recorded more than five inches of rain from Thursday (the 21st) night into Saturday (the 23rd). A graphical depiction of the rainfall during passage of this wave is shown on Figure 6.

Note that location of rainfall in excess of eight inches point out that most of the heaviest rain occurred over mountainous terrain (compare with inset) or where showers were moving upslope (as near Ponce) from the beach to the slopes. Through almost this entire event the low level winds had a south or southeast component, implying that convection was enhanced by orographic lift.

Reported rainfall from rain gages across Puerto Rico, in addition to the major airports on Saint Thomas and Saint Croix are listed in Table 1.

| Reported rainfall (in.) from Aug. 21 to Aug. 24, daily totals ending at 1200 UTC (700 am AST) on designated date | | | | |
|---|----------------|----------------|----------------|--------------|
| Reporting Rain Gage | Aug. 22 | Aug. 23 | Aug. 24 | Total |
| Rio Portugues near Tibes | 0.02 | 3.25 | 9.94 | 13.21 |
| Lago Carite at Spillway near Guayama | 0.33 | 6.34 | 5.86 | 12.53 |
| Villalba – Bo Apeadero | 0.16 | 3.08 | 8.17 | 11.41 |
| Adjuntas – Lago Garzas | 0.01 | 4.41 | 6.79 | 11.21 |
| Ciales – Lago El Guineo | 0.18 | 3.05 | 7.76 | 10.99 |
| Guayanilla | 0.00 | 2.76 | 7.95 | 10.71 |
| Ponce below Portugues Dam | 0.00 | 2.10 | 7.89 | 9.99 |
| Lago Adjuntas near Adjuntas | 0.60 | 2.78 | 6.34 | 9.72 |
| Lago de Matrullas | 0.69 | 2.11 | 6.90 | 9.70 |
| Lago Cerrillos at Damsite | 0.00 | 2.66 | 6.96 | 9.62 |
| Lago Vivi near Utuado | 0.64 | 1.92 | 6.40 | 8.96 |
| San Lorenzo – Qb Blanca | 0.11 | 4.78 | 3.72 | 8.61 |
| Rio Grande near El Verde | 1.46 | 1.97 | 4.93 | 8.16 |
| Pueblito del Rio | 0.47 | 3.59 | 4.02 | 8.08 |
| Patillas – Bo Marin | 0.48 | 4.32 | 3.14 | 7.94 |
| Rio Icacos near Naguabo | 0.76 | 3.44 | 3.72 | 7.92 |
| Rio Canovanas near Campo Rico | 1.06 | 2.77 | 4.08 | 7.91 |
| Guayama – Canal de Guamani at Hwy 15 | 0.11 | 6.80 | 0.95 | 7.86 |
| Vaqueria El Mimo, near Caguas | 0.17 | 3.15 | 4.34 | 7.66 |
| Lago Luchetti at Dam above Yuaco 4 NW | 0.00 | 3.52 | 4.09 | 7.61 |
| Lago Guayabal Damsite near Juana Diaz | 0.01 | 1.46 | 6.13 | 7.60 |
| Rio Humacao at Las Piedras | 1.09 | 3.47 | 2.93 | 7.49 |
| Rio Caguitas at Villa Blanca | 0.52 | 3.09 | 3.86 | 7.47 |
| Aibonito | 0.16 | 3.70 | 3.50 | 7.36 |
| Barrio Beatriz near Caguas | 0.45 | 2.73 | 3.96 | 7.14 |
| Guayama | 0.44 | 4.96 | 1.68 | 7.08 |
| Rio Caonillas at Palma Paso | 0.42 | 1.43 | 5.16 | 7.01 |
| Lago Icacos at Damsite | 0.83 | 3.15 | 2.82 | 6.80 |

| Reported rainfall (cont.) from Aug. 22 to Aug. 24, totals ending at 1200 UTC (700 AST) am on designated date | | | | |
|---|----------------|----------------|----------------|--------------|
| Reporting Rain Gage | Aug. 22 | Aug. 23 | Aug. 24 | Total |
| Guanica RAWS | 0.43 | 1.68 | 4.56 | 6.67 |
| Rio Jacaguas at Juana Diaz | 0.00 | 1.46 | 5.12 | 6.58 |
| Lago Loco near Yauco | 0.07 | 2.30 | 4.20 | 6.57 |
| Lago Yahuecas near Adjuntas | 0.22 | 2.48 | 3.81 | 6.51 |
| Bairo Arriba near Aguas Buenas | 0.58 | 3.07 | 2.82 | 6.47 |
| Cidra – Lago de Cidra | 0.32 | 3.01 | 2.94 | 6.27 |
| Rio Maunabo at Lizas | 0.53 | 4.35 | 1.30 | 6.18 |
| Rio Grande de Loiza | 1.46 | 1.87 | 2.80 | 6.13 |
| Gurabo | 0.34 | 2.72 | 3.01 | 6.07 |
| Rio Espiritu Santo near Rio Grande | 1.10 | 1.83 | 3.12 | 6.05 |
| Ciales | 0.26 | 1.62 | 4.14 | 6.02 |
| Rio de La Plata at Proyecto la Plata | 0.21 | 3.78 | 1.96 | 5.95 |
| Rio Coamo at Highway 14 | 0.03 | 2.84 | 3.01 | 5.88 |
| Rio Valenciano near Juncos | 0.33 | 3.08 | 2.46 | 5.87 |
| Rio Limon above Lago Dos Bocas | 0.96 | 1.20 | 3.70 | 5.86 |
| San Lorenzo – Qb Salvatierra | 0.15 | 3.73 | 1.90 | 5.78 |
| Rio Tanama near Utuado | 1.24 | 2.29 | 2.20 | 5.73 |
| San Lorenzo – Qb Arenas | 0.33 | 3.85 | 1.53 | 5.71 |
| Juncos | 0.24 | 2.90 | 2.54 | 5.68 |
| San Juan Luis Munoz Marin Int'l Airport | 0.64 | 1.34 | 3.54 | 5.52 |
| Rio Inabon at Real Abajo | 0.00 | 1.41 | 4.04 | 5.45 |
| Cyril E. King Aprt, Charlotte Amalie, St. Thomas | 2.08 | 3.14 | 0.05 | 5.27 |
| Caguas, Bo Canaboncito | 0.21 | 2.09 | 2.94 | 4.62 |
| Henry E. Rohlsen Aprt, Christiansted, St. Croix | 0.17 | 2.05 | 0.00 | 2.22 |

Table 1. Daily rain gage reports for each 24 hour period ending at 1200 UTC (800 am AST), August 22-24, 2014.

c. Watches and Warnings

While tropical storm force winds were not expected to occur the amount of moisture was recognized as a threat in spite of continuing dry soils throughout the islands. A flash flood watch was issued early on the 21st (Thu). The watch was in effect beginning late that night and would continue until Saturday morning, though it would later be extended in time for Puerto Rico into Sunday.

During the August 22-24 period (Friday-Sunday) there were flash flood warnings issued for Saint Thomas and Saint John, Vieques, and for 41 of the 78 municipalities on mainland Puerto Rico. In addition, there were flood advisories (less serious than a warning) for Saint Croix, Culebra, and 67 municipalities on the mainland. The only significant area that escaped flooding was the northwest part of Puerto Rico, where less than three inches of rain occurred (Fig. 6). Table 2 details the watches and warnings that were issue by the National Weather Service at San Juan.

| Watches and Warnings | | |
|---|--|--|
| Type of Issuance | Location | Date/Time (AST) |
| Flash Flood Watch, for late Thu Night (early 22 nd) thru Saturday morning (23 rd) | All of Puerto Rico, including Vieques and Culebra, and U.S. Virgin Islands | Aug. 21 / 935 am |
| Flash Flood Warning | Vieques | Aug. 22 / 1242 pm |
| Flash Flood Warning | Saint Thomas, Saint John | Aug. 22 / 1245 pm |
| Flash Flood Warning | Arroyo, Maunabo, Patillas, Yabucoa | Aug. 22 / 243 pm, extended at 628 pm |
| Flash Flood Warning | Cayey, Cidra, Guayama, Salinas, Aibonito | Aug. 22 / 402 pm, extended at 654 pm |
| Flash Flood Watch extended through the afternoon | All of Puerto Rico, including Vieques and Culebra, and U.S. Virgin Islands | Aug. 23 / 359 am |
| Flash Flood Watch cancelled | U.S. Virgin Islands | Aug. 23 / 218 pm |
| Flash Flood Watch extended into the night | Puerto Rico, including Vieques and Culebra | Aug. 23 / 218 pm |
| Flash Flood Warning | Caguas, Cayey, Cidra, Guayama, Patillas, San Lorenzo, Aguas Buenas | Aug. 23 / 256 pm |
| Flash Flood Warning | Canovanas, Gurabo, Juncos, Las Piedras, San Juan, Trujillo Alto, Carolina, Loiza | Aug. 23 / 305 pm |
| Special Marine Warning | Coastal and Atlantic waters of Puerto Rico north to 19.5°N | Aug. 23 / 318 pm |
| Flash Flood Warning | Barceloneta, Ciales, Manati, Morovis, Orocovis, Vega Baja | Aug. 23 / 358 pm, extended at 714 pm, again at 933 pm and at 1148 pm |
| Flash Flood Watch cancelled | Vieques and Culebra | Aug. 24 / 331 am |
| Flash Flood Watch extended into the morning | Mainland Puerto Rico | Aug. 24 / 331 am |
| Flash Flood Warning | Bayamon, Cidra, Comerio, Naranjito, Aguas Buenas, Dorado, Toa Alta, Toa Baja | Aug. 23 / 424 pm |
| Flash Flood Warning | Juana Diaz, Ponce | Aug. 23 / 1032 pm |
| Flash Flood Warning | Guayanilla, Penuelas, Yauco | Aug. 23 / 1135 pm, extended at 228 am |
| Flash Flood Warning | Jayuya, Utuado, Adjuntas | Aug. 24 / 1208 am |
| Flash Flood Warning | Arecibo | Aug. 24 / 433 am, extended at 624 am, extended at 128 pm |
| Flood Warning | Barceloneta and Manati Municipalities | Aug. 24 / 609 am |
| Flash Flood Watch extended into the afternoon | Mainland Puerto Rico | Aug. 24 / 949 am |
| Flash Flood Watch cancelled | Mainland Puerto Rico | Aug. 24 / 300 pm |

Table 2. Watches and warnings issued by National Weather Service, San Juan, PR.

| Flooded Rivers from Aug. 22 to Aug. 24 (stages in feet) | | |
|--|---|--|
| River and Reporting Gage | Crest, date and time (AST) | Minor/Moderate/ Major Flood Stages (if established) |
| Rio Fajardo at Paraiso (FAEP4) | 10.06 – Aug. 22 at noon | 8.0 / |
| Rio Guayanes at Central Roig (GCRP4) | 24.17 – Aug. 22 at 600 pm | 22.0 / 25.0 / |
| Rio Grande de Loiza, below dam (TRUP4) | 22.51 – Aug. 22 at 700 pm and again at 25.96 – Aug. 23 at 300 pm | 22.0 / 32.0 / 42.0 |
| Rio de la Plata at Comerio (COMP4) | 13.85 – Aug. 22 at 700 pm and 14.28 – 800 pm | 11.0 / 13.0 / 18.0 |
| Rio Patillas near Patillas (PATP4) | 11.03 – Aug. 23 at noon | 11.0 / 15.0 / 20.0 |
| Rio Caguitas at Villa Blanca (CAMP4) | 15.52 – Aug. 23 at 100 pm | 15.0 / 19.0 / 23.0 |
| Rio Canas at Rio Canas (CAPP4) | 17.71 – Aug. 23 at 100 pm | 16.0 / 20.0 / 24.0 |
| Rio Grande de Loiza at Highway 183 (SLNP4) | 14.41 – Aug. 23 at 600 pm | 14.0 / 21.0 / 28.0 |
| Rio Toa Vaca above Lago Toa Vaca (TOVP4) | 10.03 – Aug. 23 at 800 pm | 8.0 / 12.0 / 16.0 |
| Rio Grande de Manati at Ciales (CIAP4) | 13.33 – Aug. 23 at 1000 pm | 10.0 / 12.0 / 16.0 |
| Rio Jacaguas at Juana Diaz (JUAP4) | 19.81 – Aug. 23 at 1000 pm | 14.0 / 20.0 / 26.0 |
| Rio Inabon at Real Abajo (IANP4) | 10.00 – Aug. 23 at 1100 pm | 10.0 / 16.0 / 21.0 |
| Rio Cerrillos above Lago Cerrillos (PCEP4) | 7.24 – Aug. 23 at midnight | 6.0 / 7.0 / 8.0 |
| Rio Canoillas at Paso Palma (JAXP4) | 16.39 – Aug. 23 at midnight | 16.0 / 20.0 / 24.0 |
| Rio Grande de Manati near Manati (MANP4) | 33.29 – Aug. 24 at 300 am | 25.0 / 31.0 / 34.0 |
| Rio Grande de Arecibo above Utuado (UTUP4) | 12.76 – Aug. 24 at 400 am | 10.0 / 14.0 / 18.0 |
| Rio Grande de Arecibo below Utado (UTXP4) | 17.24 – Aug. 24 at 400 am | 14.0 / 16.0 / 18.0 |
| Rio Grande de Anasco at San Sebastian (SEBP4) | 13.86 – Aug. 24 at 700 am | 11.0 / 14.0 / 19.0 |
| Rio Grande de Arecibo near San Pedro (AREP4) | 15.35 – Aug. 24 at 800 am | 11.0 / 13.0 / 17.0 |

Table 3. Rivers in Puerto Rico that reached or exceeded flood stage, and their crest levels. Those rivers reaching moderate flood stage are bolded.

Nineteen rivers reached minor flood stage in Puerto Rico during this event and five reach their established moderate stage level (Table 3). The only river gages that

approached major flood stage (came within about 9 inches) were Rio Grande de Manati near Manati (MANP4) and Rio Grande de Arecibo below Utado (UTXP4) which are north of the crest of the Cordillera Central. The maximum rainfall occurred on the south side of the crest (Fig. 6) and the most extreme rainfall did not contribute to rivers in the north part of Puerto Rico. However, the threat that existed on these rivers pointed out that just because very heavy rainfall is not occurring over a location that does not mean there is no danger. Most of the rain that flooded these rivers occurred well upstream, in the headwaters.

d. Damage

Damage and other impacts in Puerto Rico as reported by public and law enforcement due to the rainfall and resultant flooding are summarized below. No damage was reported in Vieques, Culebra, or the U.S. Virgin Islands.

August 22, 520 pm – Yabucoa, flash flood with Guayanes River at Calabazas Sector.

August 23, 1255 pm – Caguas, flash flood with river out of its banks at Borinquen Sector.

August 23, 238 pm – Caguas, wind damage from a thunderstorm as a tree fell over PR-183, KM 2.2 at Barrio Tomas de Castro.

August 23, 249 pm – Caguas, flash flood of Rio Caguitas.

August 23, 306 pm – San Juan, flood of McLeary Avenue at Ocean Park.

August 23, 306 pm – Ponce, road flooded at Real Anon Sector at Corral Falso.

August 23, 308 pm – Ponce, branches down on PR-10 from Ponce to Adjuntas.

August 23, 348 pm – Cayey, mudslide over PR-1 highway at intersection with PR-7722.

August 23, 418 pm – Santa Isabel, urban flooding downtown.

August 23, 1055 pm – Ponce, flash flood as PR-1 and PR-2 highways were flooded and Rio Inabon was out of its banks.

August 24, 1238 am – Yauco, flash flood from Rio Loco in Yauco. PR-121 highway was closed in Yauco.

August 24, 211 am – Yauco, flash flood as Lago Luchetti in Yauco was out of its banks. People were evacuated in Sector Luchetti.

August 24, 220 am – Utuado, flash flood as Rio Vivi and Rio Caonillas were out of their banks and impacted PR-111 highway.